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Induction Motor Speed Controller Interface Design Via Simulink External Mode

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The use of induction motors in industrial systems has been increasing rapidly in recent years. The main reasons for this it has low cost, does not require much maintenance, and has a robust structure. The scalar control method, which has a low system cost due to the need for a single sensor (speed sensor), is preferred for speed control of induction motor in this study. The speed of induction motor is realized with PI control method using TI Delfino F28335 processor and 3-phase inverter over Simulink external mode. Thanks to the designed control interface, it is possible to turn the system on and off, change the reference speed value, and observe the actual speed value numerically and graphically. In addition, the controller coefficients Kp and Ki values can be changed without reprogramming the processor.

Keywords: *Induction motor, Simulink, PI control.*

1. Introduction

The use of induction motors in industrial systems has been increasing rapidly in recent years. The main reasons for this it has low cost, does not require much maintenance, and has a robust structure [1]. Two basic methods, scalar and vector control, are used in the control of induction motors. In scalar control method, only speed of motor is sufficient as a feedback. Scalar control method aims to keep the voltage/frequency (V/f) ratio of induction motor at constant value. In vector control method, in addition to speed information, phase voltage and current values are also needed. Vector control method ensures that the induction motor can operate at low speed without reducing the torque value. While scalar control method can be performed with a single sensor (speed sensor), in vector control method at least 5 sensors (1 speed sensor, 2 voltage sensor, 2 current sensor) are required. This increases the cost considerably for small-sized applications. For this reason, the scalar control method is more preferred in most industrial applications.

The use of Simulink program was preferred in this study because of its advantages such as visual programming structure, ease of finding code errors, and access to various examples [2,3]. Thanks to the Simulink embedded coder toolbox, algorithms written in the form of block diagrams can be loaded to the processors via USB programmer interfaces. The external mode connection can also be used via Simulink in order to view and change the variables inside the processor while it is running. The external mode connection is made via USB interface with baud rate of 921600.

In this study, the speed of induction motor is realized with PI control method using TI Delfino F28335 processor and 3-phase inverter over Simulink external mode. Thanks to the designed control interface, it is possible to turn the system on and off, change the reference speed value, and observe the actual speed value numerically and graphically. In addition, the controller coefficients K_p and K_i values can be changed without reprogramming the processor. In this way, changes made on the system can be observed quickly.

The paper is organized as follows: Induction motor equations, PI speed controller for induction motor, designed Simulink control blocks, experimental setup, and external mode control interface is given in Section 2. The results are analyzed in Conclusion.

2. System Design

α-β coordinate of stator current equations of induction motor [4] can be defined as follows:

$$\frac{di_\alpha}{dt} = k_1\left(\eta\lambda_\alpha + \omega\lambda_\beta\right) - k_2 i_\alpha + k_3 u_\alpha \tag{1}$$

$$\frac{di_\beta}{dt} = k_1\left(\eta\lambda_\beta + \omega\lambda_\alpha\right) - k_2 i_\beta + k_3 u_\beta \tag{2}$$

Where $k_1 = \frac{L_m}{\sigma L_s L_r}$, $\eta = \frac{R_r}{L_r}$, $\sigma = 1 - \frac{L_m^2}{L_s L_r}$, $k_2 = \frac{R_s L_r^2 + R_r L_m^2}{\sigma L_s L_r^2}$, $k_3 = \frac{1}{\sigma L_s}$, R_s and R_r are resistances of stator and rotor, L_s and L_r are inductances of stator and rotor. Mutual inductance is expressed as L_m and ω is angular speed. Rotor flux equations are given below:

$$\frac{d\lambda_\alpha}{dt} = -\eta\lambda_\alpha - \omega\lambda_\beta + \eta L_m i_\alpha \tag{3}$$

$$\frac{d\lambda_\beta}{dt} = -\eta\lambda_\beta - \omega\lambda_\alpha + \eta L_m i_\beta \tag{4}$$

Mechanical equation is given as follows:

$$\frac{d\omega}{dt} = \frac{p}{J}\frac{L_m}{L_r}\left(\lambda_\alpha i_\beta - \lambda_\beta i_\alpha\right) - \frac{B}{J}\omega - \frac{1}{J}T_L \tag{5}$$

Here T_L is load torque, J is rotor inertia, p is number of pole pairs and B is friction factor. Integer order PI controller input expression $u(t)$ can be defined as follows:

$$u(t) = K_p e(t) + K_i \int e(t)dt \tag{6}$$

Where $e(t)$ is error function, K_p is proportional control coefficient, K_i is integral control coefficient. Designed Simulink model for embedded system is illustrated in Figure 1.

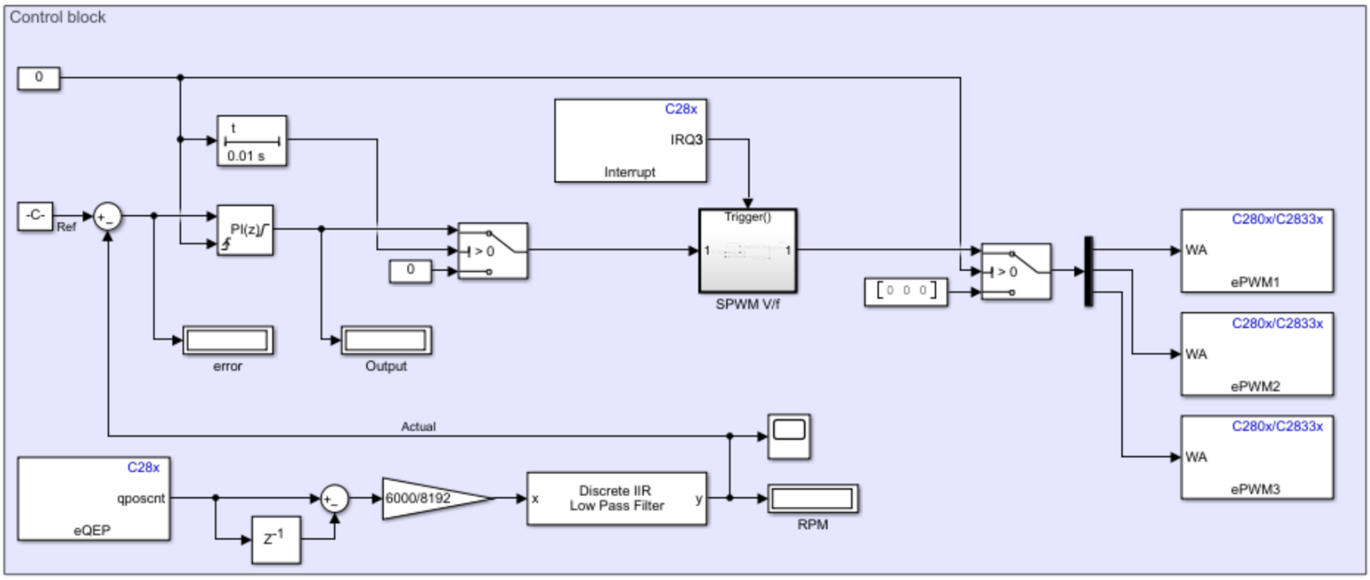

Figure 1. *Embedded code block diagram of induction motor speed control system.*

Designed external mode control interface of the system is given in Figure 2, and the experimental setup is presented in Figure 3. Thanks to the designed control interface, it is possible to turn the system on and off, change the reference speed value, and observe the actual speed value numerically and graphically.

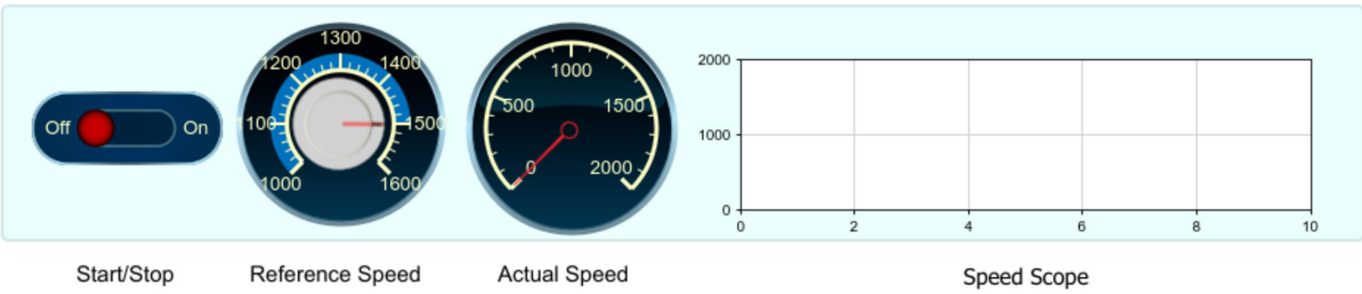

Figure 2. *External mode control interface of the system.*

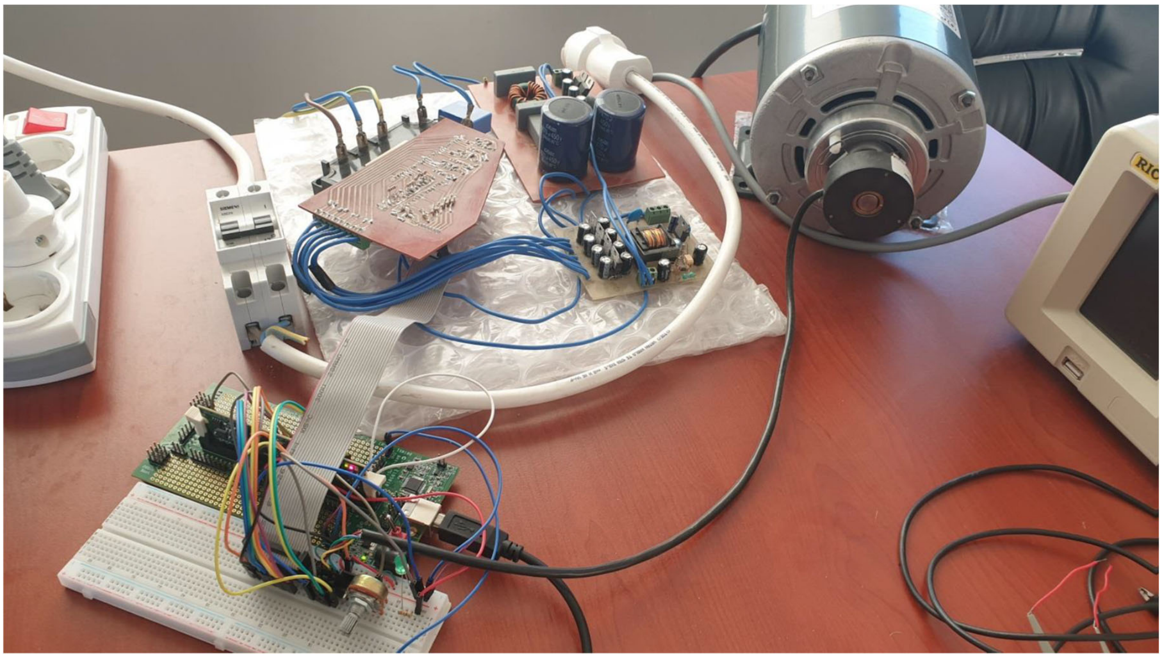

Figure 3. *Experimental setup of the system.*

The experimental setup is consists of a 60 Hz induction motor, a 2048 PPR encoder, a 3-phase IGBT inverter, TI Delfino F28335 microprocessor control card with docking station and a PC. The system has been tested by operating in external mode with 921600 baud rate via USB connection. PI control method with 10 ms cycle period is used for speed control. The encoder pulses are counted with eQEP block. IGBT switching signals are realized via ePWM blocks with complementary mode. Operation of the system with the control interface over external mode is given in Figure 4. Thanks to this interface, it is possible to monitor and analyze data online.

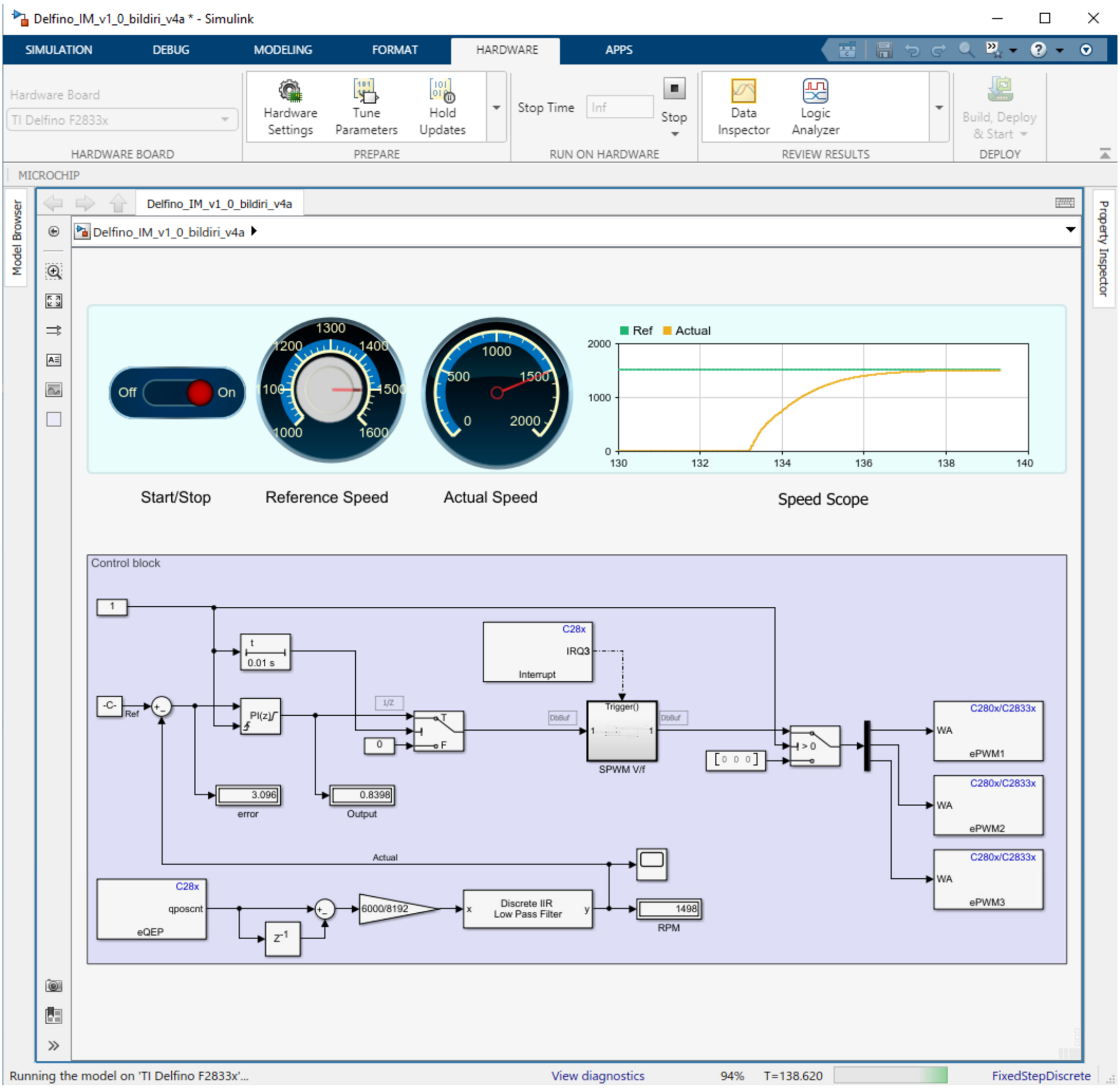

Figure 4. *Monitoring and changing the parameters on Simulink external mode while the system is operating.*

3. Conclusion

In this study, the speed of induction motor is realized with PI control method using TI Delfino F28335 processor and 3-phase IGBT inverter over Simulink external mode. Algorithms written in the form of block diagrams using the

Simulink embedded coder toolbox are loaded in the microprocessor used with the USB programmer interface. Thanks to the designed control interface, it is possible to turn the system on and off, change the reference speed value, and observe the actual speed value numerically and graphically. With this interface, desired parameter changes can be made quickly without reprogramming the processor. With the high-speed connection (921600 baud rate) used, data exchange can be provided without data loss and without additional load on the microprocess.

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